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THROUGHPUT ANALYSIS FOR VIDEO TRANSMISSION IN LTE DOWNLINK

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ABSTRACT

Fourth generation of mobile technology has adopted LTE as the wireless standard for the development of future mobile communication. It is a proven technology that allows systems to have high data rates, bandwidth flexibility and spectral efficiency. The scheduling feature employed in LTE systems ensures proper allocation of resource blocks to user equipments. Video transmission in downlink LTE system with eNodeB as transmitter and user equipment as receiver is realized. The throughput performance for video transmission in an LTE Rayleigh fading channel and the variation in throughput performance based on the amount of video bits to be transmitted by the UE and different fading environments are considered. The performance of the system is affected by the amount of video data being transmitted and also by the different fading environments.

***KEYWORDS:** 4G, LTE, LTE Frame, Resource Block, Scheduling, LTE System Toolbox & Downlink Throughput*

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Original Article

INTRODUCTION

The emerging new applications such as Multimedia Online Gaming, mobile TV and streaming contents, along with the increase of mobile data usage have stirred the 3rd Generation Partnership Project (3GPP) to work on the Long-Term Evolution (LTE). LTE is a standard for wireless data communications technology and an evolution of the GSM/UMTS standards. LTE, whose radio access is called Evolved UMTS Terrestrial Radio Access Network (E-UTRAN), is expected to considerably improve end-user throughputs, sector capacity and reduce user plane latency.

4G defines the fourth generation of mobile technology which employs Long Term Evolution (LTE) as its wireless standard. The advancement to 4G systems was necessitated by the essentiality of better performing systems and associated techniques. 4G has proved to be an evident improvisation of its predecessor mobile technologies in terms of data rate, network capacity and spectral efficiency. It supports a fully IP based packet switched network where its systems are compatible with the pre-existing technology systems. It provides a data rate of 100 Mbps for high speed users and of one Gbps for low speed users. Adaptive Modulation and Coding schemes (AMC), multi carrier modulation schemes such as OFDM, multiple antenna techniques such as MIMO, advanced receiver designs and retransmissions employed ensure a high speed error free data transfer [1].

LONG TERM EVOLUTION

In LTE, the base station is known as the evolved node B or eNodeB (eNB) and the mobile station is called the user equipment (UE). In the downlink, eNodeB is the transmitter and UE is the receiver. The processes of transmission mode selection, precoding, resource allocation and scheduling takes place at eNodeB. LTE system

architecture mainly comprises of the UE, LTE EUTRAN or eNodeB and LTE Evolved Packet Core (EPC). These network elements are connected to each other through various interfaces [2].

LTE standard provides high data rate, high capacity, lower latency and flexible bandwidth features. The goal of LTE was to increase the capacity and speed of wireless data networks using new digital signal processing techniques and modulations. It mainly focuses on increased network coverage and spectral efficiency with peak data rates of 300 Mbps in the downlink and 75 Mbps in the uplink thereby supporting higher user mobility. The flexibility offered in accessing the bandwidth allows the network operators to access the bandwidth ranging from 1.4 to 20 MHz.

Most general technologies such as MIMO and OFDM are used by the LTE standard. With MIMO technology the channel capacity and the throughput is improved. OFDM is a multicarrier transmission scheme where higher bit rate data streams are divided into lower bit rate data streams and transmitted using different orthogonal carriers. Thus, it mitigates the effect of inter symbol interference (ISI) and reduces the requirement of highly complex equalizers at the receiver end. LTE uses OFDMA in the downlink and SC-FDMA in the uplink as the multiple access techniques. Radio resource management procedures allow the efficient utilization of radio spectrum in LTE systems.

RESOURCE BLOCK AND LTE FRAME STRUCTURE

One of the main processes taking place at the eNodeB is resource allocation and scheduling. Resource allocation is performed across both time and frequency domain. Allocation of resource elements or in particular resource block allocation is performed. A resource element (RE) is one subcarrier along the frequency domain and one OFDM symbol along the time domain. A resource block (RB) comprises of 12 subcarriers along frequency domain and 7 OFDM symbols along the time domain. It constitutes around (12*7) = 84 resource elements as in Figure 1. A subcarrier is having a bandwidth of 15 kHz. A resource block has a bandwidth of (12*15) =180 kHz and a duration of 0.5ms.

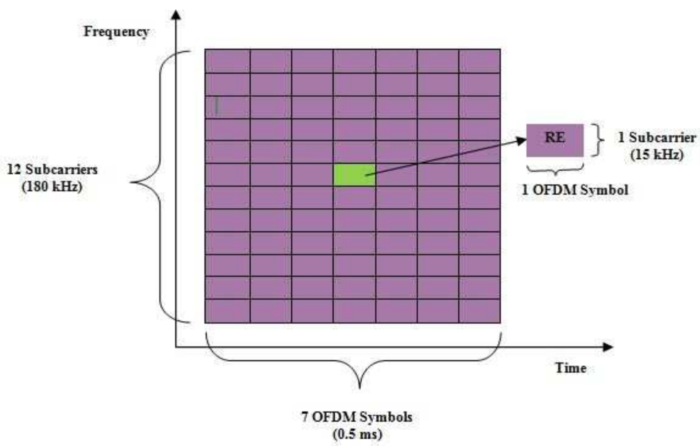

Figure 1: Resource Block

An LTE subframe is of duration 1ms and is composed of one resource block pair. LTE frame is equivalent to 10 LTE subframes. It is of duration 10ms. LTE system performs the process of scheduling where user equipments are allocated with certain number of resource blocks depending upon their demand to send or receive the information bits. Thus information bits are mapped onto the allocated RBs and are transmitted as LTE subframes or frames through LTE physical layer to the receiver end.

LTE Physical layer can be simulated using the LTE System Toolbox in MATLAB R2014a version. Certain physical signals and physical channels are used to model the LTE physical layer. These include two physical synchronization signals and five physical channels. This is clearly depicted in Figure 2 showing the LTE subframe of 1 ms duration.

The synchronization signals are primary synchronization signal (PSS) and secondary synchronization signal (SSS). They are for cell identity and frame timing. Physical channels are used to carry user and control data. These include Physical Broadcast Channel (PBCH), Physical Downlink Shared Channel (PDSCH), Physical HARQ Indicator Channel (PHICH), Physical Control Format Indicator Channel (PCFICH) and Physical Downlink Control Channel (PDCCH).

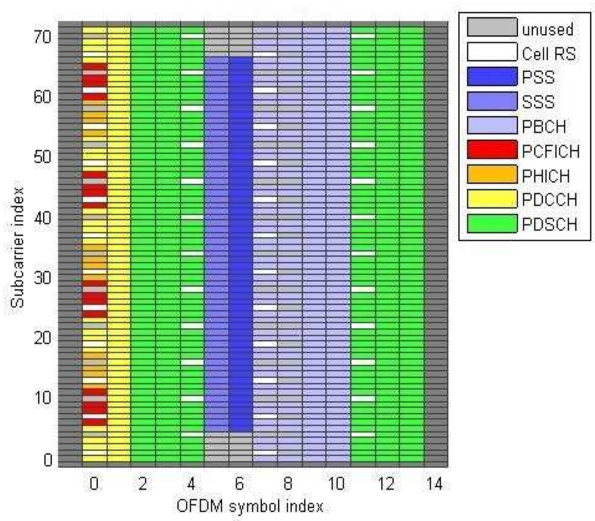

Figure 2: LTE Subframe of 1ms Duration

PBCH transmits a 24-bit master information block (MIB) value whose first 3 bits indicates the LTE system bandwidth used. PDSCH transmits the user data bits. It occupies majority of the LTE subframe or resource grid. PHICH carries the transmission acknowledgement bit or the retransmission request bit to ensure error free user and control data. PCFICH transmits the control format indicator (CFI) value indicating the number of OFDM symbols used by the control data. It helps in decoding the other data and control channels. PDCCH transmits the downlink scheduling and control information. It gives information on the resource blocks which carry the data and also the demodulation scheme to be employed at the receiver. There are also Cell specific Reference Signals (Cell RS) which is used by UE to find the downlink power from an eNodeB [3].

SYSTEM MODEL

The system model consists of a downlink transmitter and a downlink receiver. The downlink transmitter is the eNodeB and the downlink receiver is the user equipment (UE). The downlink system with eNodeB and UE connected by an LTE fading channel is shown in Figure 3. At the transmitter or eNodeB a downlink scheduler as in [4] is employed. It schedules several user equipments in downlink served by a single eNodeB based on the amount of video data bits to be received by each UE and the quality of the channel between the eNodeB and a particular UE.

Figure 3: Downlink System Model

Scheduled user equipment is allocated with resource blocks to receive video data bits. At the eNodeB, the video bits to a particular UE are mapped onto the allocated resource blocks in the LTE subframes for transmission. The LTE frames constituting the subframes are transmitted through an LTE fading channel to the UE. At the receiver or UE, the subframes are demodulated and decoded to obtain the video data bits. The throughput can be calculated as the ratio of number of successful video bits received to the simulation time.

SIMULATION SCENARIO

The LTE system can establish a connection between the eNodeB and UE through the LTE Physical Layer. The simulation platform of MATLAB R2014a version with inbuilt LTE System Toolbox is utilized. This allows the design, verification and simulation of downlink LTE systems. The LTE physical layer can be modeled with the physical signals and physical channels using the LTE system toolbox. There are several inbuilt functions in the toolbox to facilitate the easy implementation of the LTE system model [5]. Table I shows the simulation parameters used for the implementation of LTE downlink system. The simulation parameters are prefixed with “enb” to realize an LTE downlink system.

Table 1: Simulation Parameters

Simulation Parameters	Value
Reference channel (RC)	R.10
System Bandwidth	10 MHz
Number of Resource Blocks	50
Transmission Scheme	Transmit Diversity
Number of Subcarriers	600
Number of OFDM symbols per subframe	14
Number of Transmit Antennas	2
Number of Receive Antennas	2
Channel Model Type	Rayleigh Fading
Delay Profile	Off,EPA,EVA,ETU
Doppler Frequency	5 Hz,70 Hz,300 Hz
Total Subframes	10
Cyclic Prefix	Normal
Duplex Mode	FDD
Transmission Time Interval	1ms

The video bits to the scheduled UE is mapped onto the PDSCH indices in LTE subframes, OFDM modulated for each SNR value for each LTE frame to obtain the transmit resource grid. The transmit resource grid from the eNodeB is transmitted to the UE through an LTE Rayleigh faded channel. At the receiver, the resource grid is received and OFDM demodulated. The grid is then decoded with the help of channel estimated grid to obtain the transmitted video bits. Along

with the decoding of video bits, the block CRC value is also obtained. The block CRC value is used in determining the throughput performance at each SNR point.

SIMULATION RESULTS

The downlink transmitter employs the downlink scheduler which schedules and allocates the downlink receiver with resource blocks for receiving the transmitted video data bits. Figure 4 shows the resource block allocation done by the eNodeB for 10 user equipments based on their priority value calculated as per the scheduling algorithm in [4]. There are six resource blocks considered for an LTE bandwidth of 1.4 MHz. Among these 6 RBs, some of them are allocated to each user.

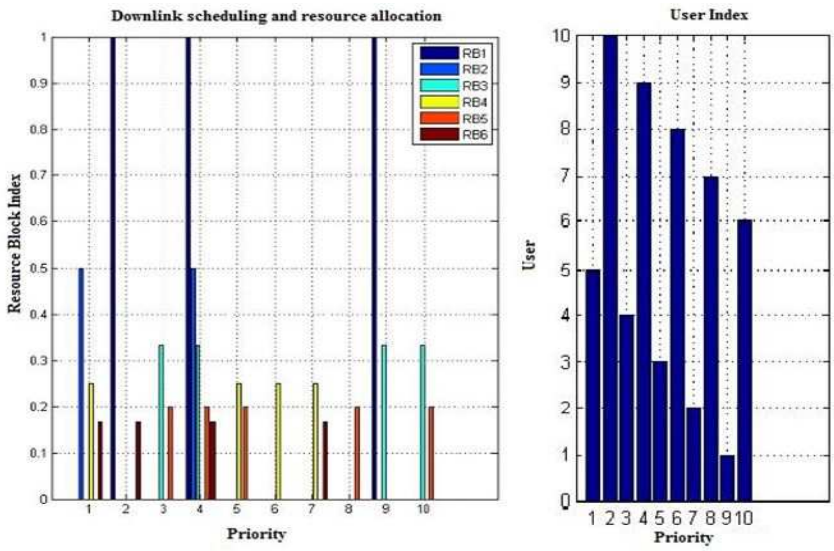

Figure 4: Resource Allocation

It is clear from Figure 4 that User 5 is given resource blocks RB2, RB4 and RB6 having maximum channel quality. User 8 is given only one resource block RB4. User 9 is provided with RB1, RB2, RB3, RB5 and RB6 except RB4 i.e. five out of six resource blocks are allocated to User 9 for transmission in one TTI (Transmission Time Interval) of 1 millisecond. Similarly all other users are provided with resource blocks. The scheduler can be extended to work over any LTE bandwidth ranging from 1.4 to 20 MHz. The difference will be in the number of resource blocks that can be utilized by the UE to receive the video data.

Throughput performance for video transmission in LTE downlink is obtained by using the simulation parameters mentioned in Table I. An LTE bandwidth of 10 MHz providing 50 resource blocks was used for the purpose. The transmission mode “Transmit Diversity” helps in realizing a MIMO system with 2 transmit and 2 receive antennas. The channel model of Rayleigh fading channel with a delay profile of Extended Vehicular A (EVA) type with Doppler frequency 70 Hz was chosen to transmit the video bits. It took 26 LTE frames of duration 10 ms each to completely transmit the video bits to a particular UE. So it took around 260 ms for transmission of around 1018681 bits. The throughput obtained for the transmission of video bits is as shown in Figure 5.

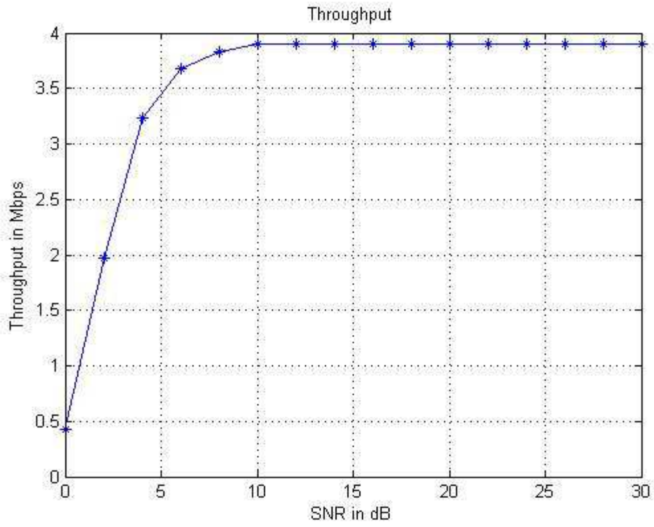

Figure 5: Downlink Throughput Performance for Video Transmission

At low SNR ranges, the number of bits that each subframe can transmit is less compared to that at high SNR. As a result the throughput is less for lower SNR range. At high SNR value, the throughput becomes a maximum constant value of 3.9 Mbps.

As the length of video bits to be transmitted varies, the number of LTE frames required to transmit them also varies. Here 3 user equipments are considered which receive different length of video bitstream. For the different payload sizes, it took 20, 40 and 260 ms duration LTE frames for transmission. The variation in the throughput for varying video bit lengths is as shown in Figure 6.

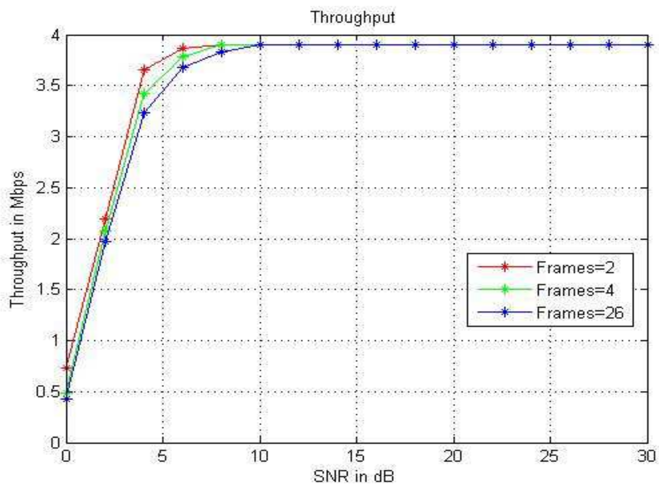

Figure 6: Downlink Throughput for Different Video Bit Length

For all the three cases the throughput is less than the maximum constant value for SNR values below 10 dB. For low SNR values, throughput for lower video bitlength transmitted is more than that for higher video bitlength. For SNR value above 10 dB, the throughput attained by all the three users is the same.

The effect of various channel conditions on the throughput was studied by providing different channel delay profiles. This was obtained by changing the delay profile as Off, EPA, EVA and ETU. For a delay profile “Off”, an

environment with no fading was obtained. The throughput performance corresponding to this delay profile was observed. Similarly, the delay profile was changed to Extended Pedestrian A (EPA), Extended Vehicular A (EVA) and Extended Typical Urban (ETU) with a Doppler frequency of 5, 70 and 300 Hz to obtain a UE with a speed of 3, 30 and 120 kmph. EPA, EVA and ETU represents low, medium and high delay spread environments.

From Figure 7, it is evident that the throughput performance of the system degrades as the amount of fading increases. For fading free environment, the observed throughput was high when compared to other fading environments. The least throughput was observed for the high delay spread environment with ETU delay profile. The performance of EVA channel model was better than ETU channel model and that of EPA delay spread environment was comparable to that of fading free environment

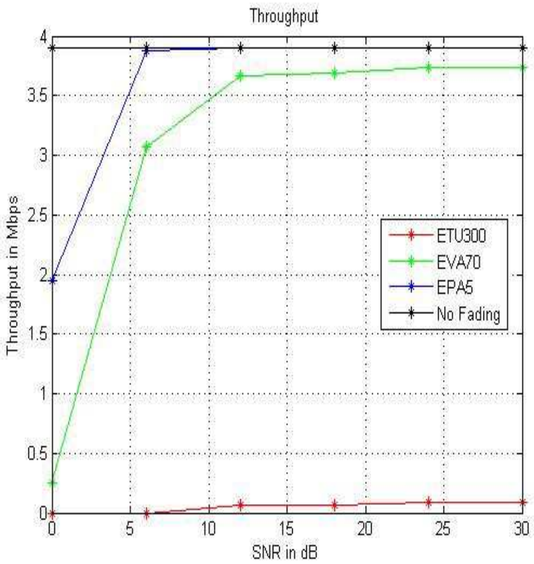

Figure 7: Downlink Throughput for Varying Channel Condition

CONCLUSIONS

LTE has evidently been the standard supporting the fourth generation of mobile technology. A downlink communication system is established with eNodeB as the transmitter and user equipment (UE) as the receiver. Downlink scheduling is a feature in LTE downlink systems allocating resource blocks to the user equipment for receiving their data. Using the inbuilt functions in the LTE system toolbox, a downlink system is modeled for video bit transmission. The throughput performance for video transmission over the LTE frames is studied. The performance of the system is affected by the amount of video data being transmitted and also by the different fading environments.

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